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TIME EVOLUTION OF GLOBAL EQUIVALENT CURRENT SYSTEM ASSOCIATED WITH PARTIAL RING CURRENT (EXTENDED ABSTRACT)

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Introduction

It is well known that a strong dawn-dusk asymmetry exists in the geomagnetic horizontal component (H) during a geomagnetic storm especially in the main phase when the *Dst* field develops. Such a dawn-dusk asymmetry has been attributed to a partial ring current system which closes via field-aligned currents and ionospheric current (*e.g.*, FUKUSHIMA and KAMIDE, 1973). However, the location of the current circuit and its temporal evolution are not yet clear.

In this paper, we investigate how a 'partial ring current' system is formed during a geomagnetic storm by drawing average equivalent ionospheric current vectors at various storm times using one minute resolution geomagnetic field data. The equivalent ionospheric currents are derived from ground geomagnetic perturbation vectors assuming that the perturbations are generated by the ionospheric currents having uniform sheet structure. It should be noted that the perturbations on the ground are not necessarily generated by the ionospheric currents especially in middle latitudes on which we discuss in this paper.

Data and method of analysis

The one minute resolution geomagnetic data are used to draw the equivalent current system. These data were obtained from the Intermagnet CD-ROMs, Image magnetometer chain, STEP Project 6.4 CD-ROMs, and the data published through the World Data Center system.

To calculate the equivalent current vectors, the following procedure was adopted.

(1) The monthly average values on 5 international quiet days are subtracted from the data for each stations.

(2) The coordinates are transformed to the dipole system by taking into account the local magnetic anomaly for the stations where the *HDZ* coordinate system is used.

(3) The vectors are rotated 90° clockwise and multiplied by a constant to get the equivalent height-integrated current density.

The equivalent current vectors are then averaged in the mesh on the Cartesian coordinate system where the northern hemisphere is projected on the equatorial plane. The averages are taken at each epoch of storm development, *i.e.*, the elapsed time (T)

from the start of the storm main phase.

The storms analyzed in this paper were selected with the following criteria:

(1) The minimum of the *Dst* field (*i.e.*, the maximum of the absolute value) is less than -50 nT.

(2) The variation of the *Dst* field from the beginning of the decrease to the minimum point is rather monotonic, that is, the recovery of the *Dst* field during the period is relatively small.

(3) The main phase defined as above lasts at least 3 hours.

With the above criteria, we selected total 294 storm events for the period from 1984 to 1995. The number of ground geomagnetic stations used in this study is about 30 to 70 which increases year by year.

Results and discussion

Figure 1 shows an example of geomagnetic storms we examined in this paper. The upper panel indicates the ASY-*D*, -*H*, SYM-*D* and -*H* indices (*e.g.*, IYEMORI and RAO, 1996) and the lower four diagrams show the equivalent currents at each epoch during the storm main phase in the polar region. In this storm, the SYM-*H* (*i.e.*, *Dst* field) starts to decrease at 0100 UT and reaches the minimum at 0745 UT. We define this interval as the storm main phase though we have a bump which starts at 0600 UT. The equivalent ionospheric currents at 0030, 0130 and 0230 UT show the eastward currents on the afternoon side which form a part of two cell convection pattern though the night side vortex is much greater. At 0330 UT, most part of the polar region is covered by the clockwise current vortex and the eastward currents are seen at the latitudes lower than 60° on the evening side probably because of the expansion of the auroral oval.

Figure 2 shows the averaged equivalent current vectors at the four epochs for the storm main phase in the northern hemisphere. The upper left panel indicates the pattern at the start of the main phase ($T=0$). The relatively intense current vectors in low-latitudes are caused by the sparseness of the stations as well as the method of taking the mesh point. To subtract the daily variation caused by the ionospheric dynamo, the equivalent current vectors of one hour before the start of the main phase are averaged and subtracted. To subtract the symmetric ring current effect as well as the effects from the magnetopause and the tail current, the *Dst* field was subtracted at each mesh point assuming that the effect decreases with a cosine of dipole latitude.

At $T=0$, the eastward current in the afternoon sector is weak. We see tiny but coherent vectors pointing north-west at around 16–18 MLT near 40° latitude. These small vectors develops as time goes on and form an equivalent return flow on the low-latitude side of the eastward electrojet, which is often regarded as the equivalent current effect of the partial ring current system. It should be emphasized that the current pattern starts from afternoon side and develops toward evening side, which possibly indicates the importance of the convection electric field rather than the particle injection from night-side in the formation of the partial ring current system.

In the early morning sector, the southward flow starts to develop in the subauroral region around $T=30$ min and develops to form the dawn-side return flow of the westward electrojet. We note that the current flow near midnight is southward which is opposite to the effect of substorm wedge current system. This southward equivalent

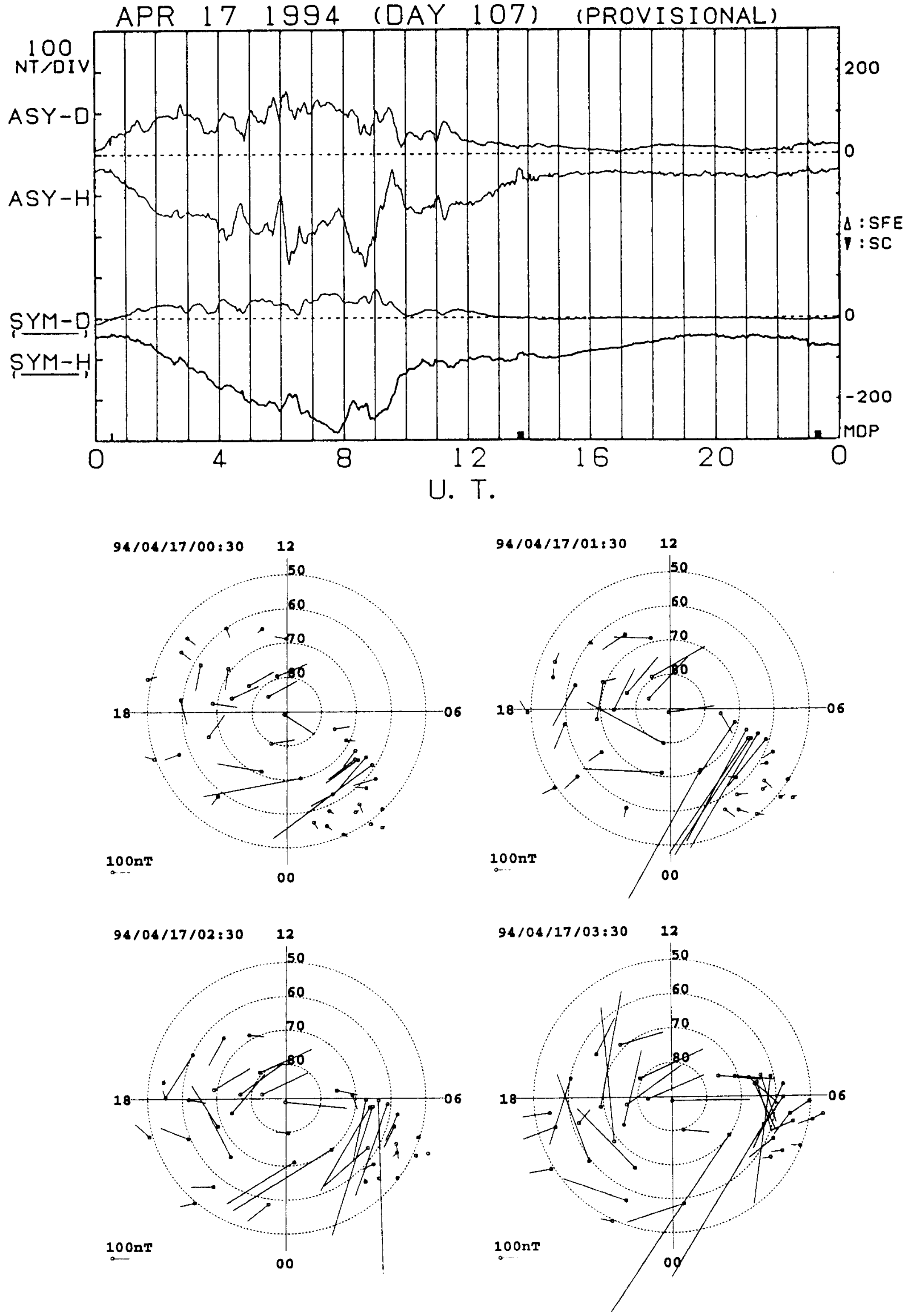

Fig. 1. An example of geomagnetic storm used in this study (upper panel) and the equivalent current vectors at four epochs in the main phase (lower panels) on the dipole latitude-magnetic local time plane.

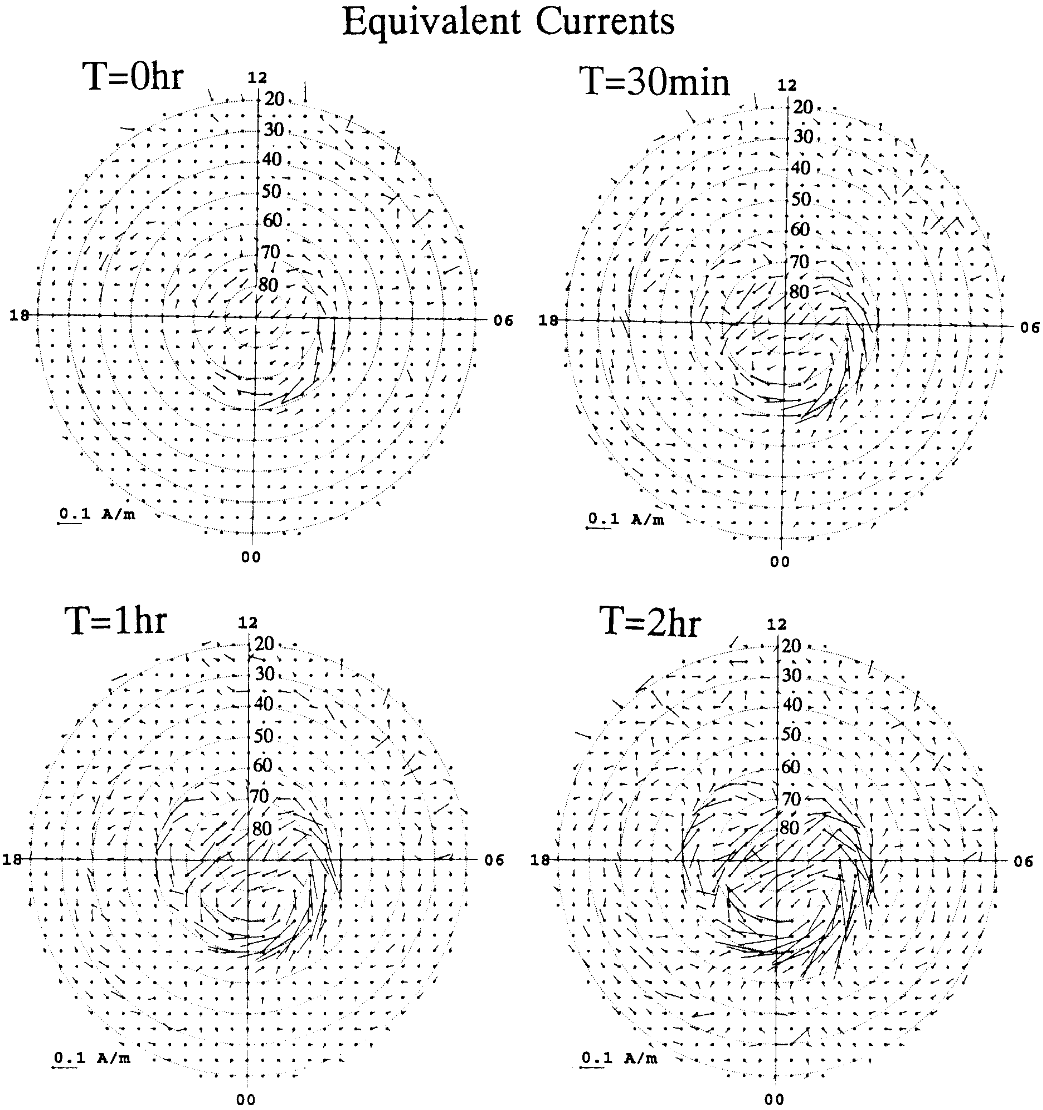

Fig. 2. Averaged equivalent current vectors at the beginning of storm main phase (upper-left panel, T=0), at T=30 min (upper-right), T=1 hour (lower-left) and T=2 hours (lower-right), respectively. The effects from symmetric ring current, magnetopause current and the tail current are subtracted assuming that they generate a uniform field in north-south direction at the Earth.

current suggests the existence of net upward field-aligned current on the night-side forming a part of the partial ring current system. The slight time difference in the development of return current system could be the effect of the substorm wedge currents on the morning side return current.

Another point to be noted is that the average current pattern in the polar region is rather similar and show two cell convection pattern though the morning side vortex is large and strong. This is probably because the southward component of the interplanetary magnetic field is, in general, strong during storm main phase (*e.g.*, RUSSELL *et al.*, 1974).

Figure 3 shows the difference in the equivalent current pattern for different UT. The left panel shows the currents for the interval from 2100 to 0900 UT and the right

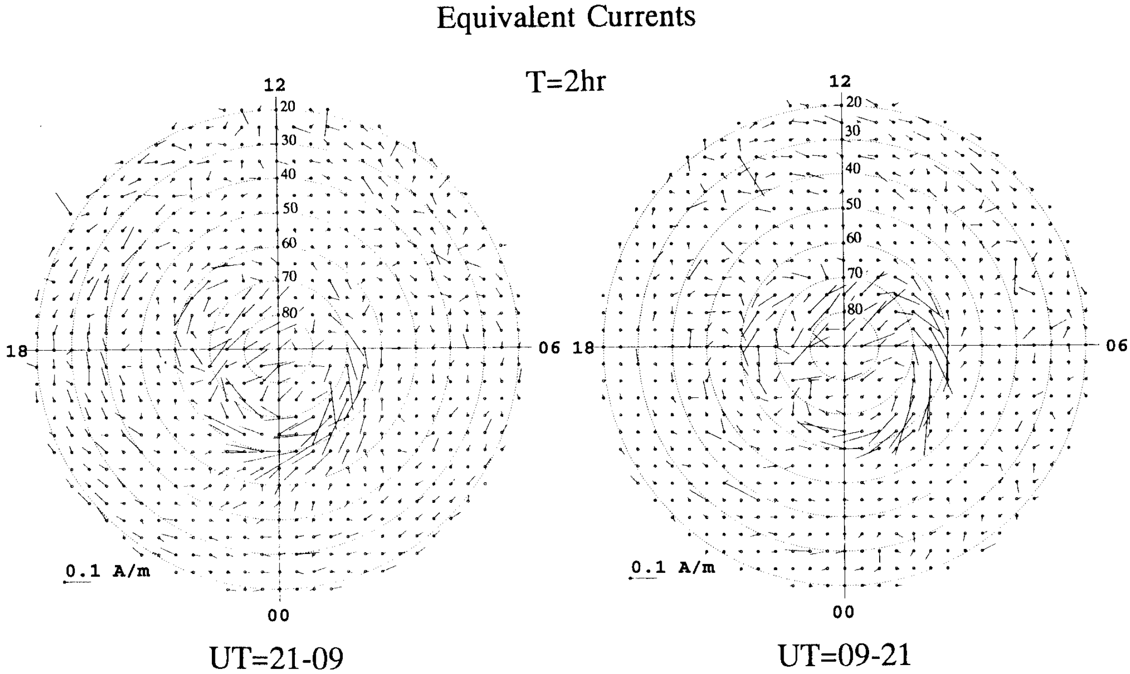

Fig. 3. Averaged equivalent current vectors at T=2 hour from the start of the main phase for the interval of UT between 2100 and 0900 (left) and that between 0900 and 2100 (right), respectively. The European stations located in the region of smaller inclination of geomagnetic main field are in the early morning (left panel) and in the afternoon sector (right panel).

one shows the interval between 0900 and 2100 UT. In the afternoon-side subauroral- and mid-latitudes, the northward current is more clear for the latter case (*i.e.*, the right panel in Fig. 3). On the other hand, the southward currents around midnight subauroral region are more clearly seen for the interval from 2100 to 0900 UT (the left panel in Fig. 3). These universal time dependence of the equivalent current system could be explained by a distortion of the geomagnetic main field from the dipole. That is, the inclination of the geomagnetic field in European and north Atlantic region is smaller than the other longitudes for the same dipole latitude, and the effects of field-aligned currents on the ground are larger for smaller inclination in European and north Atlantic regions.

In this paper, we discussed only the equivalent currents in the storm main phase defined by the *Dst* field. To investigate the three dimensional current system and its temporal variation, we need to compare with satellite observation in the magnetosphere, and such effort is in progress. It is also important to compare the observed ground magnetic variations with the interplanetary conditions, especially with the IMF-*Bz*.

Acknowledgments

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